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Enhanced Airborne and Controller Surveillance Using Automatic Dependent Surveillance-Broadcast (ADS-B)

Scope:

This paper recommends that consideration be given by RTCA's SC-186, WG-1, to expand the ADS-B message set as presently defined by RTCA DO-242 by adding additional message set elements. The objective of adding additional message set elements would be to achieve greater, shared situational awareness among pilots and controllers. Possible new message elements are defined in this paper. Potential benefits transcend safety and include airspace efficiency, capacity and security enhancements.

Background:

The notion of providing pilots and controllers with enhanced surveillance information has existed for many years. In fact, for nearly 30 years, Mode C transponders have provided height read-out information to controllers from suitably equipped aircraft. Controllers also routinely obtain other information from Mode A / Mode C transponders such as a self identification feature (i.e., "Squawk ident"), along with four unique codes (i.e., "Squawk" codes of 1200, 7500, 7600 and 7700).

Using Mode S radar technology, both the Europeans and the U.S. are actively investigating ways to downlink additional aircraft parameters through the Mode S data link. For example, there is a Technical Manual on Mode S Specific Services that identifies potential Mode S interrogated data that could reside in up to 250 registers, each of which contain upwards to 56 bits of stored data. This same architecture could be applied to the UAT, albeit bandwidth considerations are a major issue.

In Europe, a total of 36 possible Mode S downlinked parameters have, so far, been identified. Of these 36, there appear to be several clear groupings within the parameters themselves. For example, there are sets of parameters that provide the controller with specific enhanced situational awareness information. These are referred to as Controller Access Parameters (CAPs). Also, there are other parameters that, while not of direct help to the controller, appear to enhance overall ATC performance. These are generically referred to as System Access Parameters (or SAPs). Collectively, these two sets of parameters -- CAPs and SAPS -- make up what the Europeans call Downlinked Airborne Parameters (or DAPs).

The Europeans have down-selected the initial list of 36 parameters, to a more manageable and focused list of eight DAPs that could form the basis of an initial

(European) implementation of enhanced surveillance. These eight parameters include: Magnetic heading, indicated airspeed (IAS / Mach umber), selected altitude, track angle arte, vertical rate, roll angle, ground speed, and true track angle.

> *<u>Note</u>: In the absence of an internationally agreed upon CNS Glossary, the precise meaning of several of these eight parameters may be unclear. Certainly, while the Europeans understand their own requirements, without a common glossary, a precise, internationally agreed-to-meaning of terms is elusive.*

It is suggested that to effect shared situational awareness among pilots and controllers, a similar, common enhanced surveillance infrastructure within the U.S. National Airspace System (NAS) may be required. (Such an approach goes well beyond the European notion of DAP). It is believed that ADS-B can satisfy this need, contingent on adequate bandwidth, and system design. Potential benefits transcend safety and include airspace efficiency and capacity benefits. (Benefits are documented in other writings). Security surveillance of aircraft operating in the NAS can also benefit by use of these enhanced ADS-B message set "strings". This message set functionality is also seen as a key to integrate emerging ADS-B technology with the needs of the ground automation such as CTAS and URET.

It is assumed that suitably equipped aircraft would broadcast selected DAP-like data at variable rates. Additionally, other aircraft and ground stations might be able to solicit specific information when in close proximity to one another, and upon request via a broadcast data link. Surveillance platforms include ground-, air-, and space-based platforms, thereby enabling surveillance from the surface upwards.

Here is an illustrative "example" scenario. A general aviation aircraft on a night flight is involved in an accident, and its ADS-B Emergency Locator Transmitter (ELT) "unit" survives. The ELT unit, battery powered, contains specific message set elements in stored data memory. The unit, to conserve battery life, has entered a listen-only mode. An manned (or even unmanned) aircraft approaches, and upon receipt of its ADS-B state vector message set, the ELT / ADS-B device now starts to broadcast an ADS-B "in distress" message. The aircraft overhead receives this information, displays it to the pilot, and sets in stage the process to send help.

Two new ADS-B message set concepts are suggested:

- ADS-B message sets broadcast to nearby aircraft are defined as ADS-B "crosslinked" messages. (CAP)

- ADS-B messages received on the ground are defined as ADS-B "downlinked" messages. (DAP)

In this proposal, various ADS-B message sets of interest to the aircraft owner / operator are described. At present, neither the FAA air traffic control organization nor any of the constituency organizations such as ATA, AOPA, GAMA, NBAA, NATA, etc., have formally proposed or validated specific requirements. One of the objectives of this proposal is thus to stimulate thinking within the community as to the operational benefits / needs for these possible message sets. Virtually all of the material presented below is based on material presented in Appendix E of RTCA's DO-242, the ADS-B MASPS.

> *Note: Any of the message sets could be automatically broadcast at an established, preset rate, or broadcast when "triggered" by receipt of a broadcast message from a nearby aircraft (either in the air or on the ground). In the example given, ELT function would be triggered by an aircraft flying overhead, with the ELT ADS-B broadcasting messages once every 10-20 seconds, for 5 minutes. Then ceases.*

Examples of Potential ADS-B Crosslinked / Downlinked Message Sets:

The following usage description codes are used throughout this proposal:

- D = Downlink broadcast of data. (DAP)
- C = Crosslink broadcast (i.e., between aircraft) of data between aircraft. (CAP)
- U = Uplink of data from the ground-to-the-air (e.g., TIS-B)

1. Aircraft Capability / Service Levels:

This message set would include at least four new and / or consolidated ADS-B "service" levels. They include:

- Basic ADS-B situational awareness
- Pair-wise spacing applications
- Delegated separation responsibility
- Self-separation responsibility

Other than the "capability class" codes currently specified in DO-242, there are no specifically defined ADS-B enabled message set "labels" that describe the above functionality. This functionality would then "map" to application specific modular software. Software would be eligible for a TSO and in the end-state, would be an installed (or portable) appliance. Clearly, some information would need to be broadcast, say, every minute or two, while other information, such as time-critical runway incursion-related data, might need to be broadcast at a much higher rate, and perhaps only when in close proximity to the runway.

2. Aircraft sizing information or aircraft specific make / model data (D / C / U).

Supports various surface movement applications. Also enhances general aviation wake vortex modeling.

3. Actual aircraft weight (D / C). (Also enhances wake vortex modeling).

4. Runway Incursion alerting.

Possible message set candidates include:

- Aircraft heading at V-Stop (while on the airport surface) (D / C / U)
- Air / ground state: Is the aircraft physically on the ground or is it only slightly above the surface? (D / C)

Other unique runway incursion message set elements might include:

- Exterior aircraft lights on / off (D / C) This would be the basis of a simple runway incursion alerting algorithm.
- Brakes on / off (D / C)
- Percentage of engine power (D / C)
- Aborting? (D / C)

5. Fixed and "Movable" obstacles. (C / U)

Impacts the immediate airport vicinity as well as en route. Notion is to mark significant obstacles with a transmit only ADS-B system. En route flight operations (outside of TIS-B coverage) would make use of ADS-B "Class B3" message set elements such as: Obstacles -- point, line, and polygon. Also, fixed and movable obstacles, along with permanent and temporary obstacles.

6. AUTOMET / E-PIREP message set elements. AUTOMETS are defined in RTCA DO-252, but this RTCA document does not specifically address ADS-B enabled downlinked meteorological reports.

As FYI, the seven DO-252 FIS message set elements that are candidates for a combined ADS-B and AUTOMET / E-PIREP message set include:

- Static air temperature
- Wind speed / direction (i.e., the wind field velocity vector)
- Humidity
- Icing
- Turbulence
- Wind shear, and

- Liquid water content.

> *Note: Wind and air density, reported from own-ship, can be used for the wake vortex modeling application, but with less accuracy.*

All seven of these data elements (or just winds, temperature, and turbulence messages) could be broadcast at varying refresh rates, for use in the following airspace regimes:

- ♦ En route air-to-air. (Especially helpful in oceanic / remote areas, and when aircraft are flying across ATC sector boundaries. Describes wind field.)
- ♦ En route and terminal area air-to-ground. (For use by ground automation such as CTAS and URET, and for input to NWS's RUC and SNIP weather forecasting models. This once again ties ADS-B with the ground automation, and helps complete a complete systems approach where airborne systems are just one component of an overall air and ground *system*.)
- ♦ Terminal area air-to-air. (For wake vortex modeling and to provide wind field data to other aircraft to assist with FMS "4D" arrivals, parallel approaches, etc.)
- ♦ Terminal area air-to-ground. (For generating new terminal area FIS products) (D)

7. Specific flight planning and intent information, including information relating to national security.

> *Note: These message set elements are in addition to an aircraft's unique 24-bit ICAO identification code, and would be broadcast only when necessary. For instance, these message set elements might be transmitted each time the aircraft entered a new TIS-B coverage area, dependent upon need. Message set elements could also be broadcast by aircraft operating on an airport surface prior and during taxi, to afford additional surveillance monitoring for national security purposes.*

- Airport of departure (D)
- Airport of intended landing (D)
- ATC Flight Plan (ICAO format) (D)
- ADCUS (would include intended point of departure, arrival, ETA) (D)
- FMS pre-programmed flight plan (including multiple waypoints for arrival and departure intent / routings) (D / C)
- Mode Control Panel settings such as selected altitude, heading, rate of climb, rate of descent, etc. (D / C)
- Student pilot? Pilot pre-selected value. (C / D)
- Hearing impaired pilot? Pilot pre-selected value. (C / D)

- Not voice radio equipped. Pilot pre-selected value. (C / D)
- Intended destination on the airport (e.g., the parking area, gate, runway, hold-short point) This functionality would be used by both aircraft as well as vehicles. (D / C)
- Vehicle destination-on-airport conformance monitoring (D / C)

Note: Those data sets above marked with a "C" would normally be broadcast periodically, say, once every 2-5 minutes, exact time TBD.

8. Trajectory Change Point (TCP) and short-term intent information.

FMS Mode Control Panel (MCP) parameters such as aircraft heading, altitude level off height selected, target airspeed, target vertical rate, etc. Broadcast of textual SIDS (or DPs, for Departure Procedures) / STARS -- both of which describe transition routes that define multi element TCPs; could save bandwidth. (Note: This is also a high-end GA application).

Other possible short term "intent" parameters may include on condition reports for minimum approach speeds (Vref), additional TCP leg types, holding pattern information, airspeed TCP's, and RNP containment parameters.

9. Special aircraft surveillance codes (e.g., for use by various government agencies such as the DEA, FBI, SS, DOD, etc.) (D / C / U).

This user group community will need to define its needs.

10. Communication (voice) frequency being monitored (D / C)

11. Stuck mike indicator (D)

12. A means to confirm that a flight plan has been cancelled. Especially helpful for GA at non-towered airports. (D)

13. Baro altitude / GPS vertical height conformance monitoring. Useful for RVSM, GA altitude encoder ATC conformance monitoring, and for ACM integrity monitoring. (D)

A validation bit is needed to be sent from the aircraft to the ground in the event that the aircraft's avionics system detects a loss of vertical height integrity.

14. <u>Altitude (while on the ground).</u>

This ground "self-test" function would complement the airborne self-test feature, and would be used by ATC for conformance monitoring and to validate V-NAC / V-NIC. (D / U)

> *<u>Note</u>: The above functionality may be needed (in addition to the onboard self-test feature) to help GA ADS-B systems test / validate the encoder function of their ADS-B system, thereby potentially mooting the need for the 24 month transponder / encoder inspection requirement.*

15. <u>Squawk ADS-B "Ident" feature</u>. (U)

For use when aircraft are VFR, including when the aircraft's ADS-B system is operating in "anonymous mode".

16. <u>ATC request for "Stop broadcasting ADS-B altitude</u>".

> *<u>Note</u>: This functionality might be triggered by receipt of a specifically coded TIS-B message set. (U)*

17. <u>Local altimeter uplink</u>. This functionality is needed for controlled flight into terrain (CFIT) risk mitigation, and for altitude conformance. (U).

> *<u>Note</u>: Could be FIS-B or TIS-B enabled.*

18. <u>Terminal area (daily / hourly) cumulative noise exposure levels</u>. This would allow arriving and departing aircraft to disperse their noise footprint over a wide geographic area, thus helping make aircraft noise emission profiles more "people friendly". (U)

19. <u>Special Use Airspace / Temporary Flight Restricted Airspace</u>:

- Temporary Flight Restricted (TFR) airspace (e.g., its dimensions) (U)
- TFR date when effective (U)
- Times when active (U)

- Dimensions of Special Use Airspace (SUA) (actual) (U)
- SUA date when effective (U)
- Actual times when "hot" and "cold" (U)
- From civil aircraft -- The time estimate when the aircraft expected to enter / exit the SUA (D / C)

Note: In the above, DOD might want to operate a remote UAT Ground Broadcast Server (GBS), and would uplink information directly to all aircraft when within line-of-sight.

20. Special Use Airspace (continued):

- From DOD aircraft -- Military Training Route (MTR) "intent" information (D / C)
- From DOD aircraft -- The actual MTR being flown (i.e., broadcast route ID) (D / C)
- From DOD aircraft -- Size / dimensions of "blocked airspace" for a military formation flight. (D / C)

21. Emergency Locator Transmitter (ELT) and Priority Status Codes. Basic message set codes would include any specified ELT functionality so that the ADS-B unit would meet the TSO attributes of an ELT.

The ADS-B MASPS, presently defines six emergency / priority status codes, along with two spares, for a total of eight discrete message sets. Possible expansion of this section could include at least the following additional message set information:

- Indication of special need (Six parameters already defined)
- Souls on board (D / C)
- Fuel on board (D / C)
- Event time (C)

Other Considerations:

In addition to the above list, there may be additional data link message elements (part of a multi-purpose data link architecture) not fully considered in this write-up. They may include message elements unique to:

- TIS-B (ground-to-air uplink) (U)
- FIS-B (ground-to-air uplink) (U)
- DGPS augmentation signals (ground-to-air uplink) (U)

Note: GPS Regional Augmentation system (GRAS) functionality. Uplink of near LAAS-like correction signals over an ADS-B or LORAN-C RF link could enable high quality position and integrity of GA aircraft while operating on the airport surface. Such functionality may be required to help precisely geo-reference general aviation aircraft on an airport moving map for runway incursion prevention purposes. Ground-based GPS *augmentation would enable use of near CAT I level precision approaches at GA airports that were within coverage of an appropriate ground station. GRAS functionality also may be needed in areas without WAAS coverage, e.g., would facilitate affordable international GA (IGA) flight operations.*

- Runway-in-use landing threshold wind and temperature reporting (ground-to-air) (U).

  Note: This capability could also be transmitted via a local, short range, LOS RF link with a reception range needed of only 5-10 miles.

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